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RPPR Final Report
as of 25-Oct-2018

Agency Code:

Proposal Number: 70122EGRIP
INVESTIGATOR(S):

Agreement Number: W911NF-17-1-0176

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EIN:

Report Date: 14-Jul-2018

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Final Report for Period Beginning 15-Apr-2017 and Ending 14-Apr-2018

Title: System for high resolution 3D Imaging of Non-Spherical Sedimenting Particles

Begin Performance Period: 15-Apr-2017

End Performance Period: 14-Apr-2018

Report Term: 0-Other

Submitted By: Greg Voth

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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: 2

STEM Participants: 3

Major Goals: This grant funded the purchase of a new four camera imaging system for high resolution tracking of non-spherical particles sedimenting in turbulent fluid flows. These new cameras are being used (1) to increase the accuracy of the measured 3D trajectories and orientations of non-spherical particles and improve the measured solid body rotation rates, (2) to allow measurement of high resolution velocity fields around non-spherical particles along their trajectories using new algorithms for multi-camera image analysis, sometimes called "shake the box", (3) to improve the precision of 3D particle arm measurements so that measurements can resolve arm bending by fluid stresses acting on the particles and the rotational acceleration of the particles.

Accomplishments: Included in the Uploaded document.

Training Opportunities: While this grant only provided funds for equipment purchase, the new equipment has provided access to cutting edge imaging tools by the two graduate students, post-doc and two undergraduates who have used them. They will be the foundational measurement tool in the PI's lab for many years to come and will aid in the training of several of the next generation of fluid mechanics researchers.

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI

Participant: Greg Voth

Person Months Worked: 1.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

RPPR Final Report
as of 25-Oct-2018

Other Collaborators:

Participant Type: Graduate Student (research assistant)

Participant: Bardia Hejazi

Person Months Worked: 6.00

Funding Support:

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

DISSERTATIONS:

Publication Type: Thesis or Dissertation

Institution: Wesleyan University

Date Received: 22-Oct-2018

Completion Date: 11/2/17 10:26AM

Title: Non-spherical particle dynamics in Turbulence

Authors: Stefan Kramel

Acknowledged Federal Support: Y

Accomplishments

The cameras, Phantom VEO 640-S with resolution of 2560x1600 at 1400 frames per second, were purchased in the summer of 2017. After some modifications to mount and trigger the new cameras, they were installed in the fall of 2017.

The first data we have taken compared two sets of triads with rigid and flexible arms. This is a good problem to assess the capabilities of the new imaging system since detection of the small deformations requires the high image resolution. The triads used were 3D printed using two different resins supported by a sacrificial matrix on a Connex Objet500 printer. Figure 1 shows Euler angles giving the orientation as a function of time for a rigid triad sedimenting in the vertical turbulence tunnel at Wesleyan. The random fluctuations around the smooth trajectory are at the level of .001 radians, indicating the extremely high precision with which we can track these particles. It was only 6 years ago that our group published the first direct measurements of rotation rates of fibers in turbulent flows (Parsa 2012), and it is very satisfying to see the quality of these measurements having improved this rapidly.

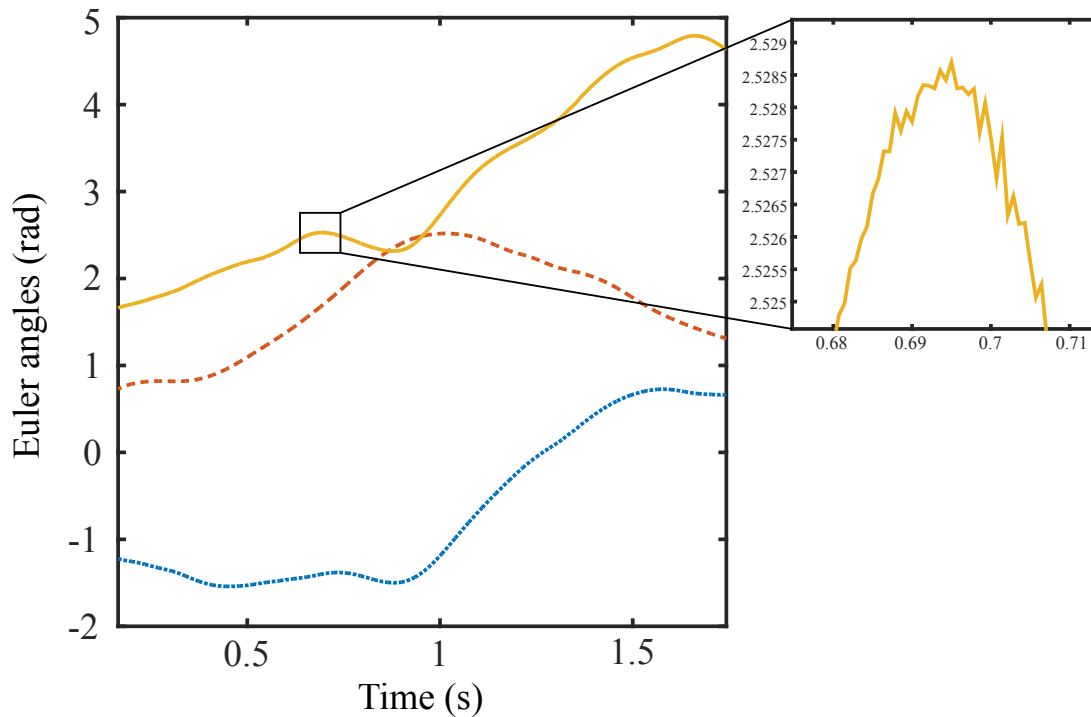


Figure 1: Euler angles as a function of time for a triad in the vertical water tunnel at $R_\lambda=192$. The subfigure shows a blow up of a time when one angle has zero time derivative in order to reveal the measurement noise.

Our first measurements of the angle between arms of a deformable triad are shown in Figure 2. We have found measurements on these particles to be very challenging as the turbulence induced deformations are small in comparison with the deviations of a non-deformed particle from the idea shape sent to the 3D printer. However, we find that for long trajectories, we can make a best fit to the equilibrium shape of the particle and then measure the deviations from this shape as a function of time. The measured deviations are on the order of .002 radians, very near our angle measurement accuracy. Work is ongoing to obtain larger deformations using higher turbulence intensity, more flexible particles, as well as to automate the determination of equilibrium shape along a trajectory.

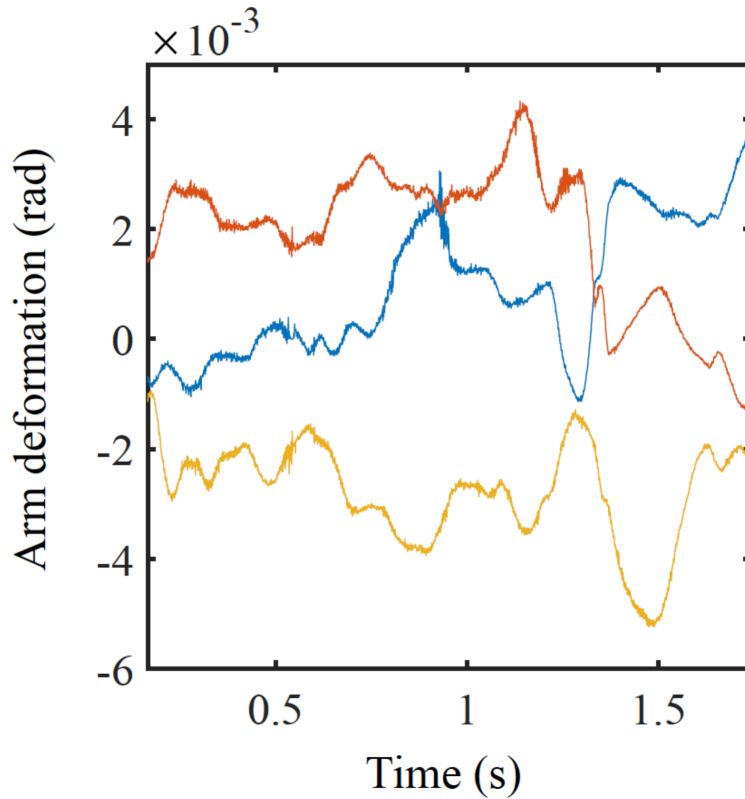


Figure 2: Deformation of each of the three arms of a triad from its undeformed state.